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(54) **TONE CORRECTION PROCESS THAT CORRECTS TONE OF IMAGE FORMED BY IMAGE FORMING APPARATUS**

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CPC ***G03G 15/556*** (2013.01); ***G03G 15/5058*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

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(57) **ABSTRACT**

An image forming unit forms an electrostatic latent image on an image carrier based on image data converted by a conversion unit, and the image is developed by a developing portion using toner. A replenishment control unit controls an amount of the toner with which the developing portion is replenished based on a toner density in the developing portion so that the toner density in the developing portion reaches a target density. A first determination unit determines a target density based on a result of a first measurement image being measured. A correction unit corrects conversion conditions based on a result of measuring a second measurement image and a correction condition. A second determination unit determines the correction condition based on the target density determined by the first determination unit.

15 Claims, 12 Drawing Sheets

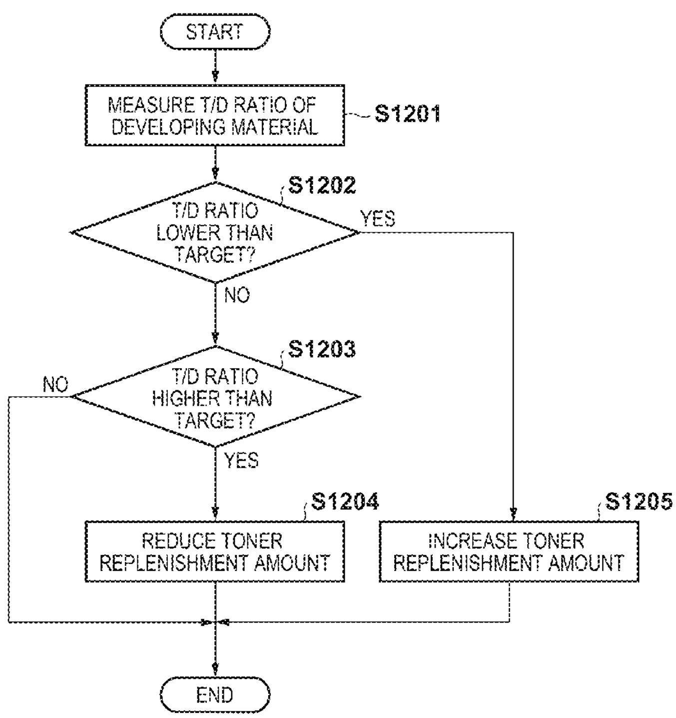


FIG. 1

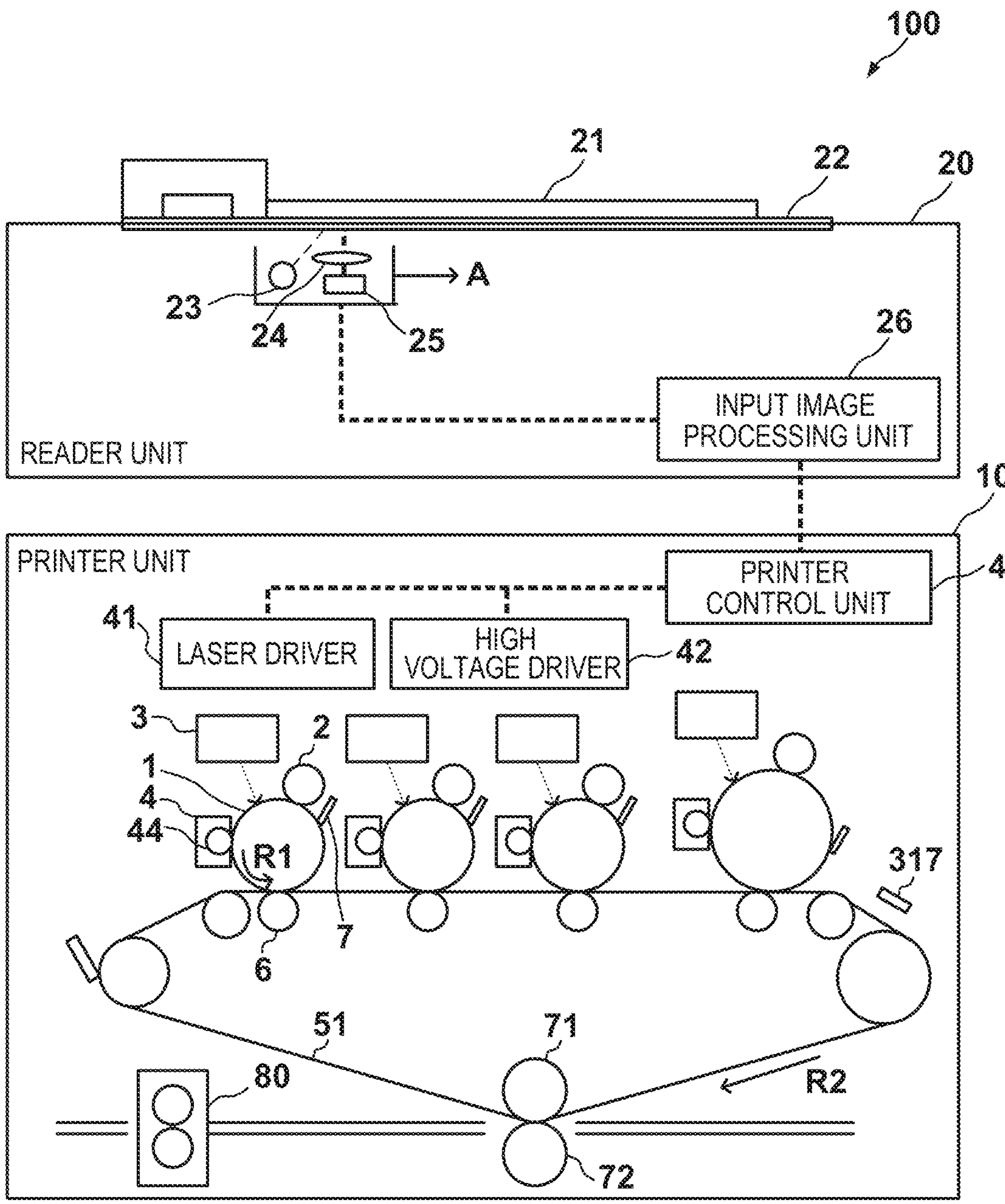

100
21
22
20
A
23
24
25
26
INPUT IMAGE PROCESSING UNIT
READER UNIT
10
PRINTER UNIT
PRINTER CONTROL UNIT
40
41
LASER DRIVER
HIGH VOLTAGE DRIVER
42
3
2
1
4
44
R1
317
7
6
51
71
80
R2
72

FIG. 2

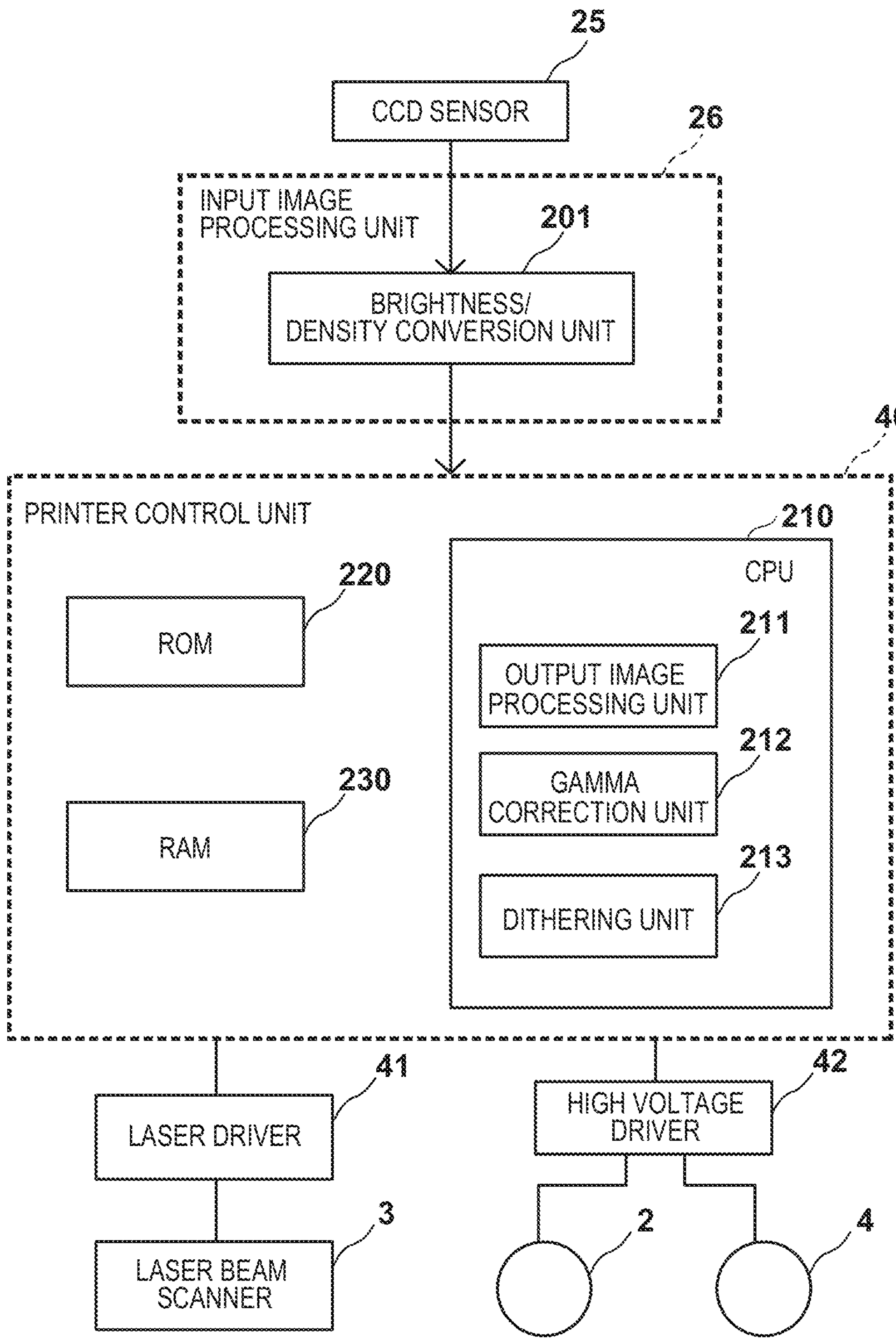

25
CCD SENSOR
26
INPUT IMAGE PROCESSING UNIT
201
BRIGHTNESS/ DENSITY CONVERSION UNIT
40
PRINTER CONTROL UNIT
210
CPU
220
ROM
211
OUTPUT IMAGE PROCESSING UNIT
212
GAMMA CORRECTION UNIT
230
RAM
213
DITHERING UNIT
41
LASER DRIVER
42
HIGH VOLTAGE DRIVER
3
LASER BEAM SCANNER
2
4

FIG. 3

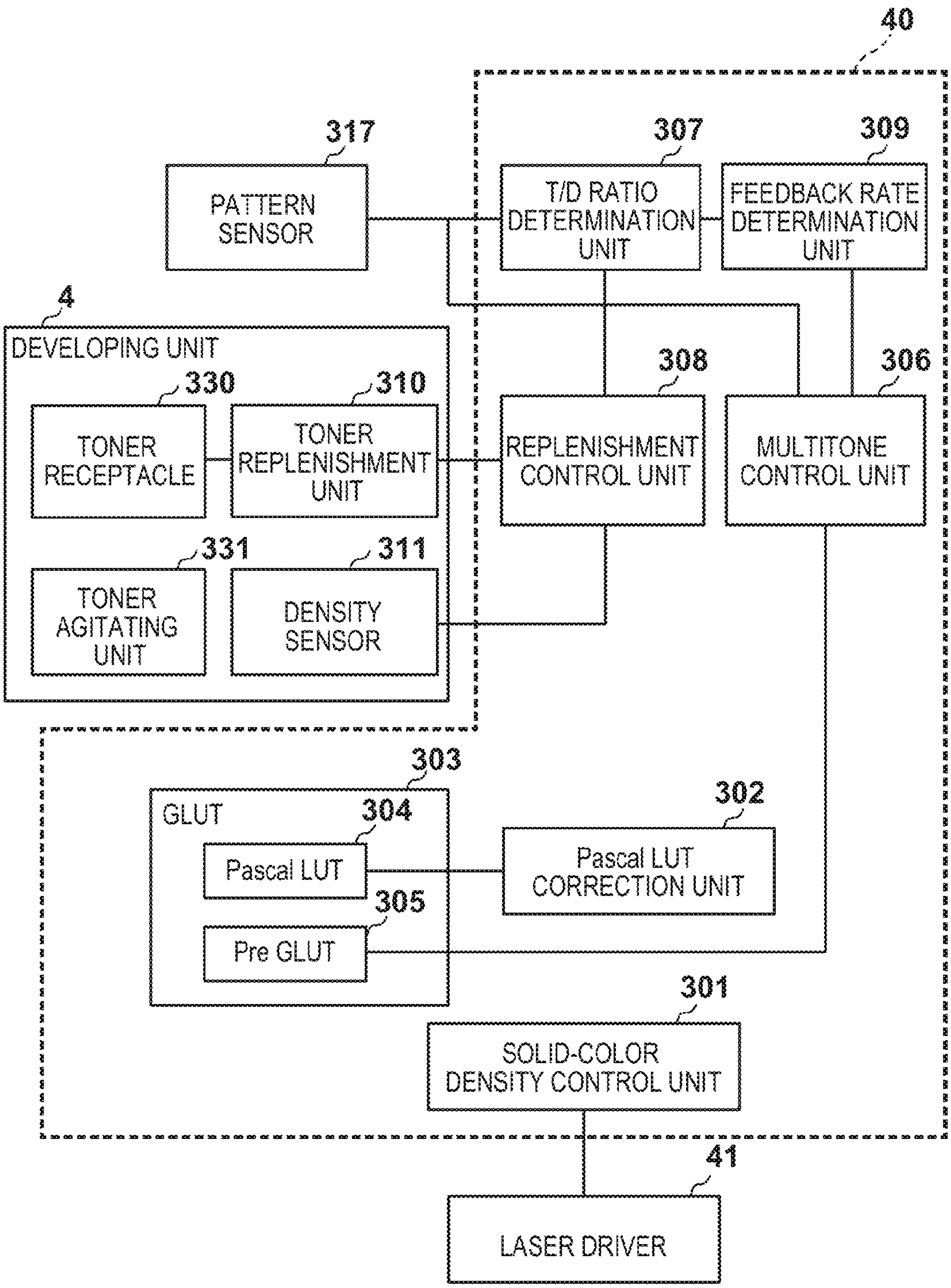

40
317
PATTERN SENSOR
307
T/D RATIO DETERMINATION UNIT
309
FEEDBACK RATE DETERMINATION UNIT
4
DEVELOPING UNIT
330
TONER RECEPTACLE
310
TONER REPLENISHMENT UNIT
331
TONER AGITATING UNIT
311
DENSITY SENSOR
308
REPLENISHMENT CONTROL UNIT
306
MULTITONE CONTROL UNIT
303
GLUT
304
Pascal LUT
305
Pre GLUT
302
Pascal LUT CORRECTION UNIT
301
SOLID-COLOR DENSITY CONTROL UNIT
41
LASER DRIVER

FIG. 4

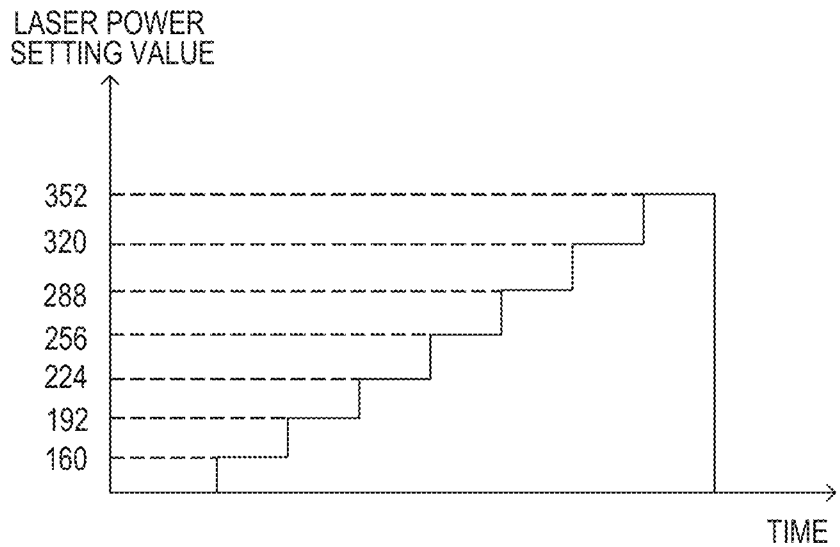

LASER POWER
SETTING VALUE
352
320
288
256
224
192
160
TIME

FIG. 5

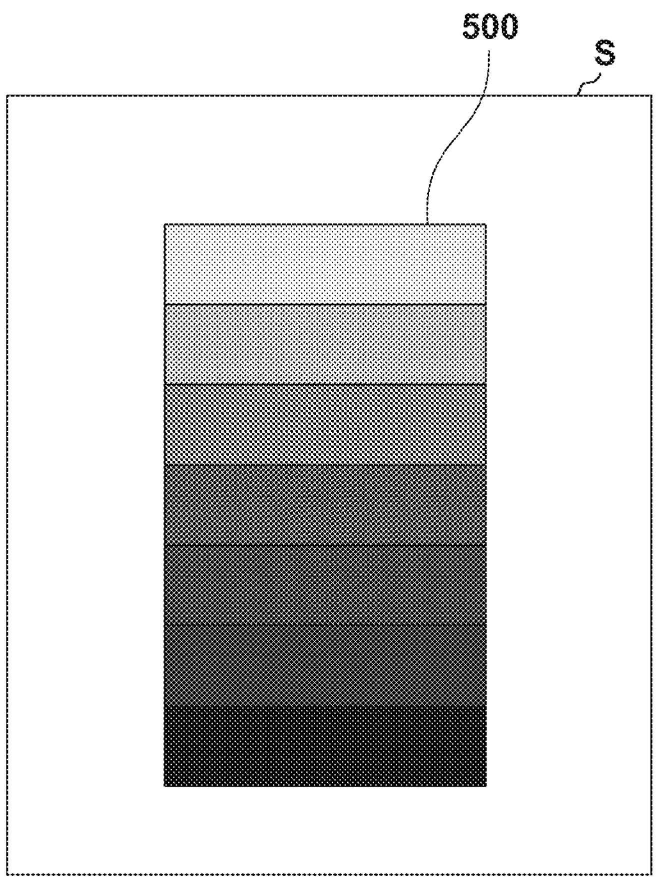

500
S

FIG. 6

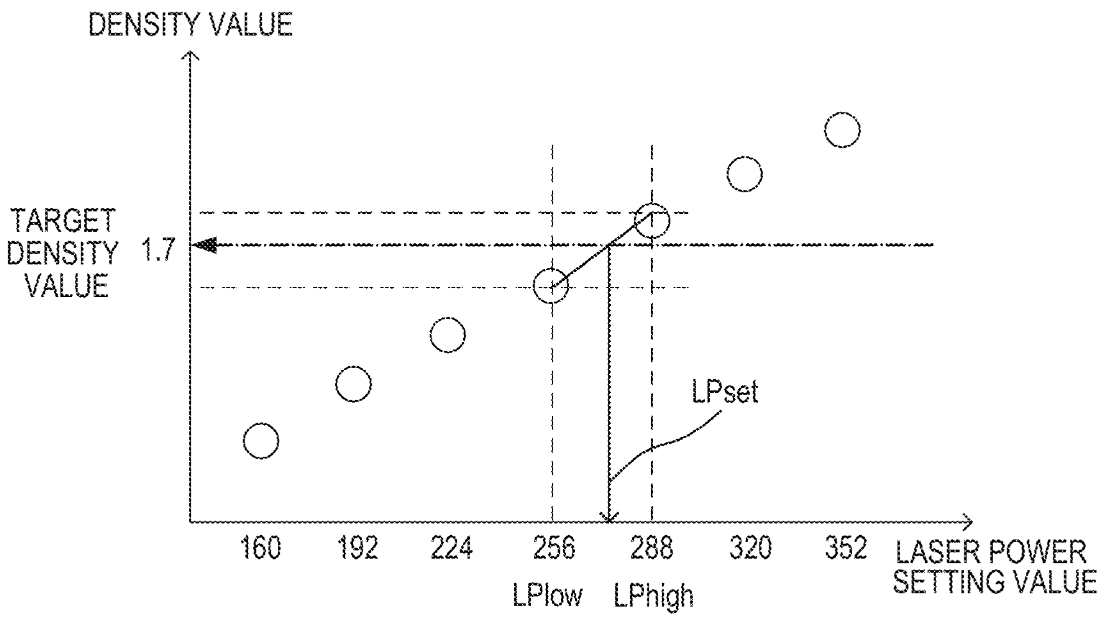

DENSITY VALUE
TARGET DENSITY VALUE
1.7
LPset
160
192
224
256
288
320
352
LASER POWER SETTING VALUE
LPlow
LPhigh

FIG. 7

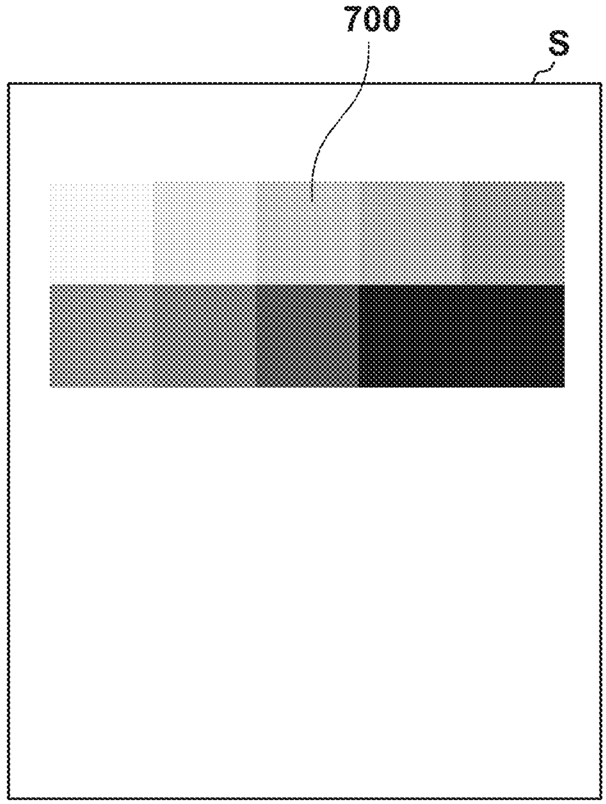


FIG. 8

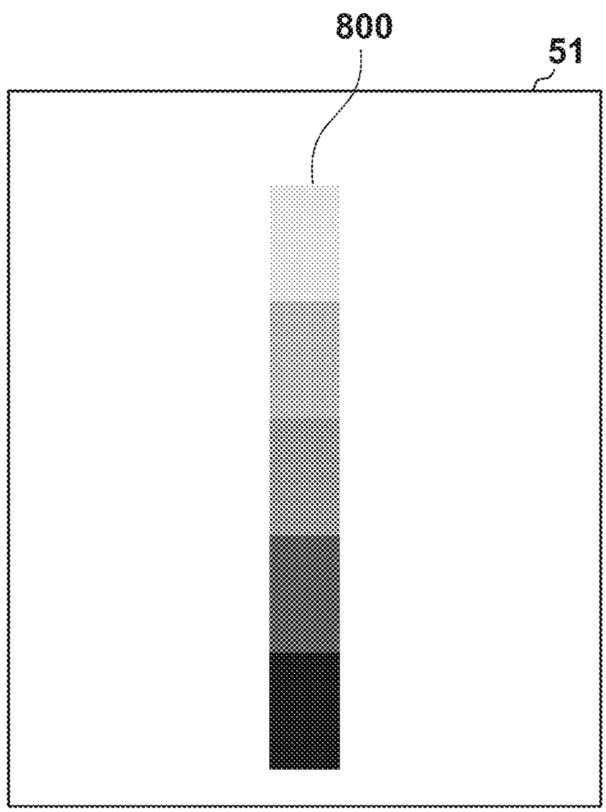


FIG. 9

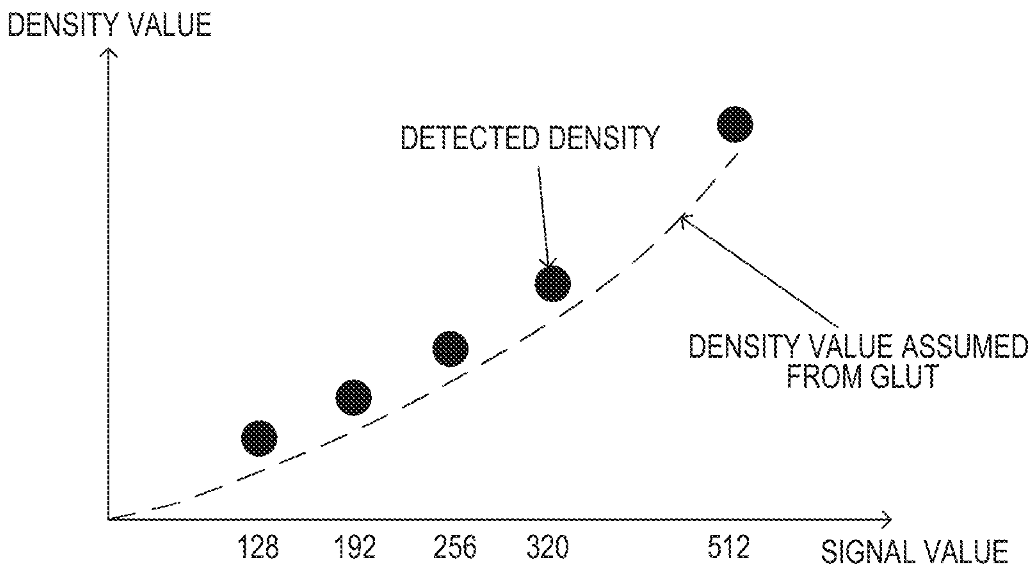

DENSITY VALUE
DETECTED DENSITY
DENSITY VALUE ASSUMED FROM GLUT
128
192
256
320
512
SIGNAL VALUE

FIG. 10

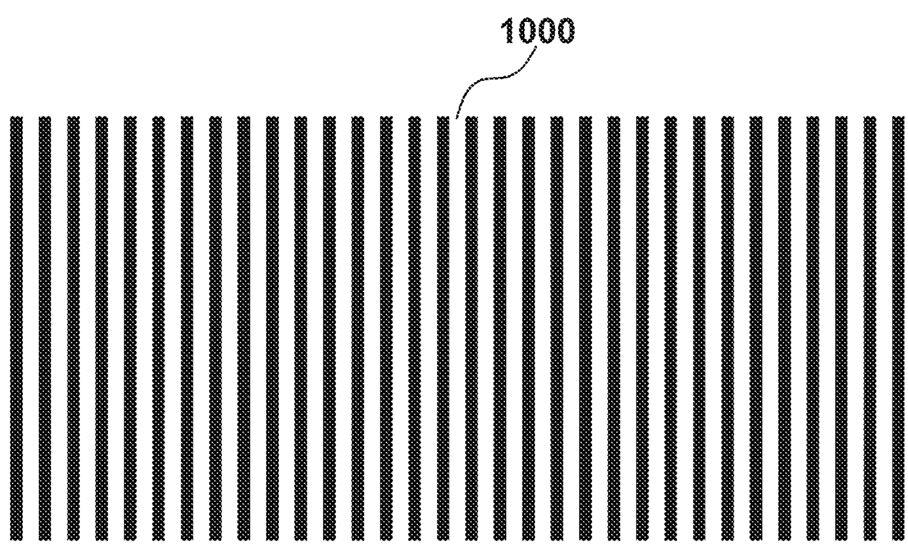

1000

FIG. 11A

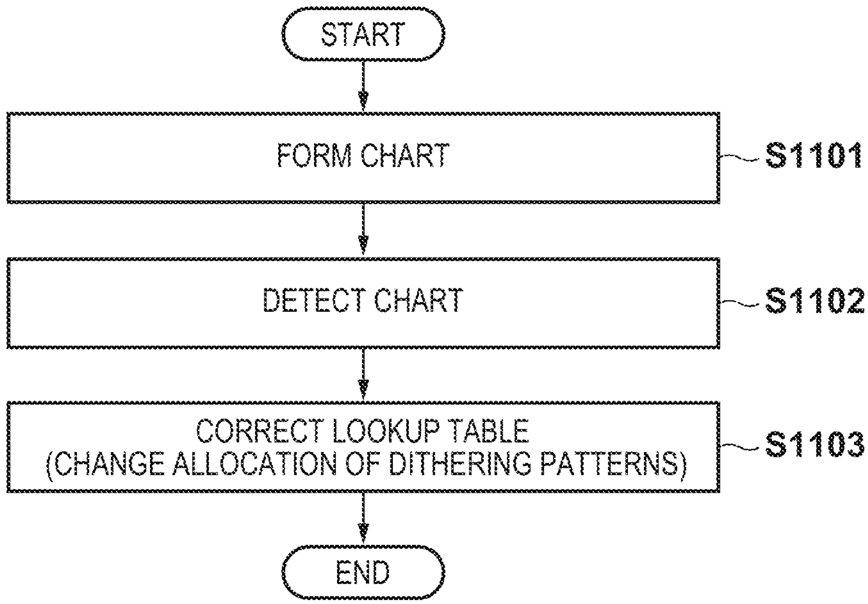


FIG. 11B

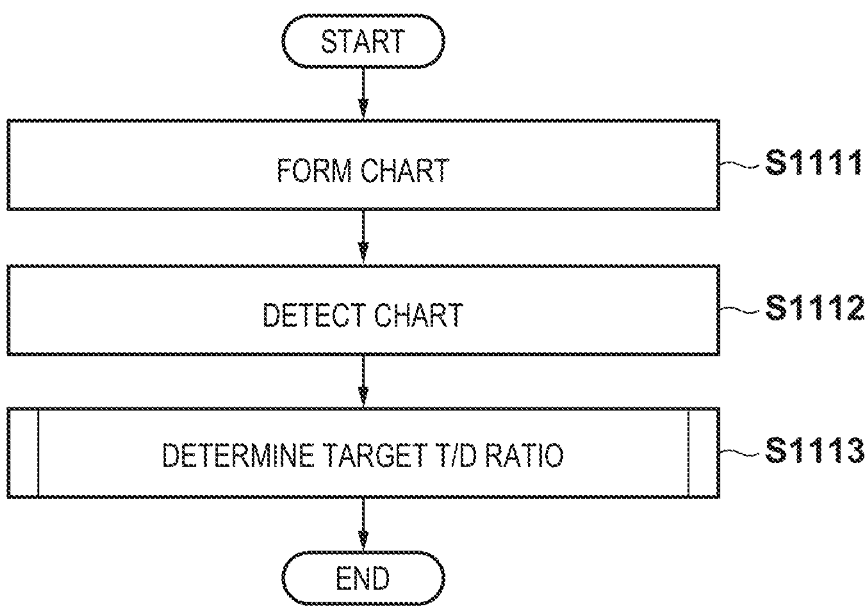


FIG. 12

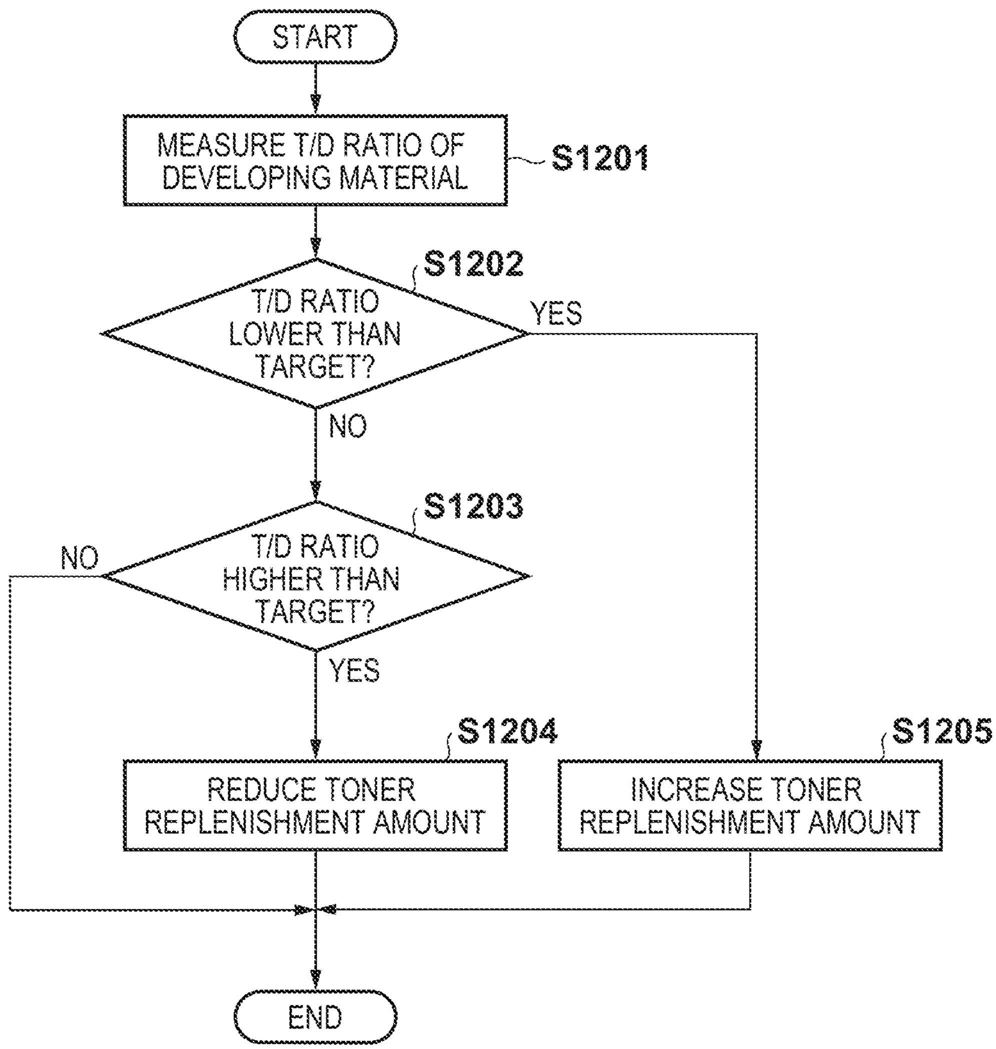

START
MEASURE T/D RATIO OF DEVELOPING MATERIAL
S1201
S1202
T/D RATIO LOWER THAN TARGET?
YES
NO
S1203
T/D RATIO HIGHER THAN TARGET?
NO
YES
S1204
REDUCE TONER REPLENISHMENT AMOUNT
S1205
INCREASE TONER REPLENISHMENT AMOUNT
END

FIG. 13

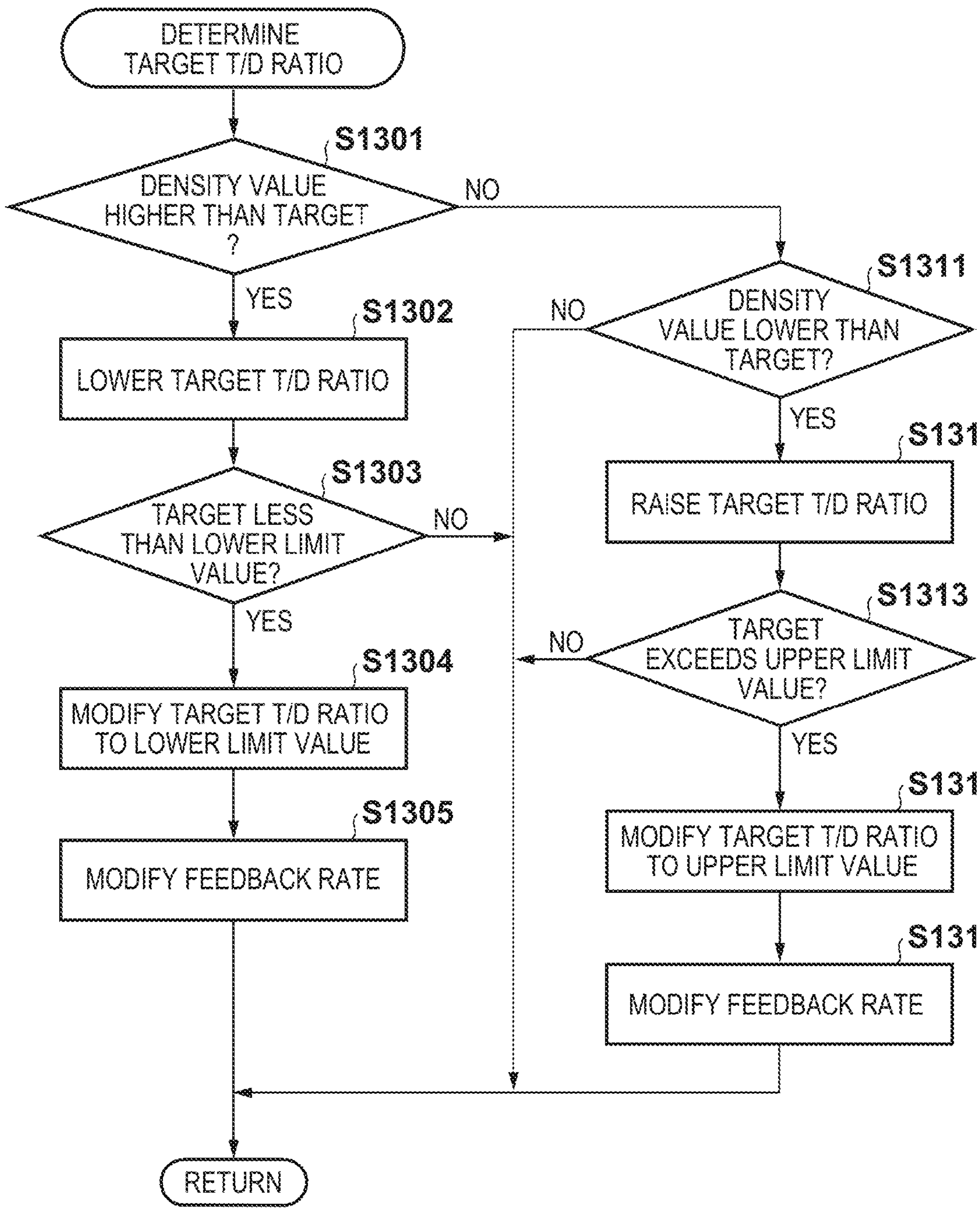
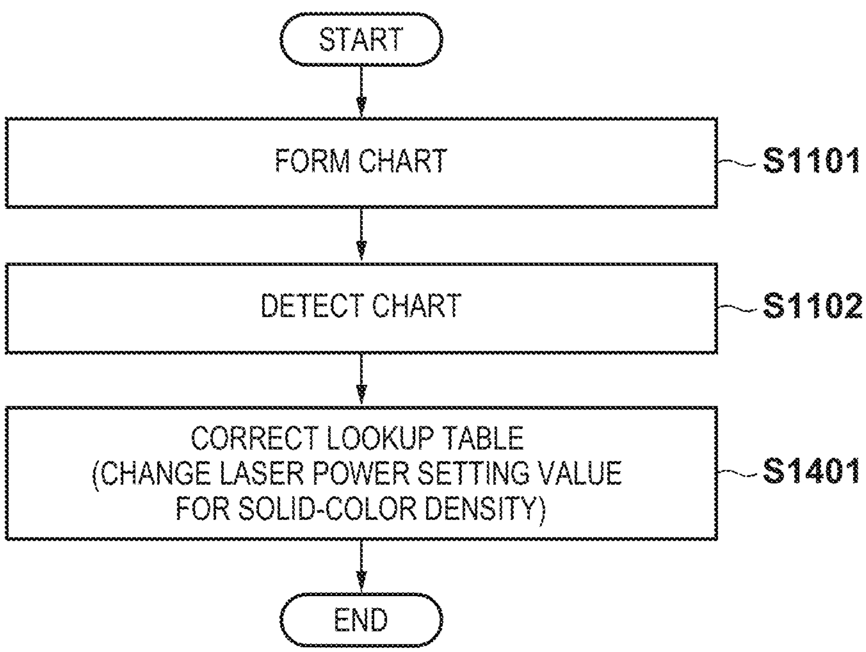
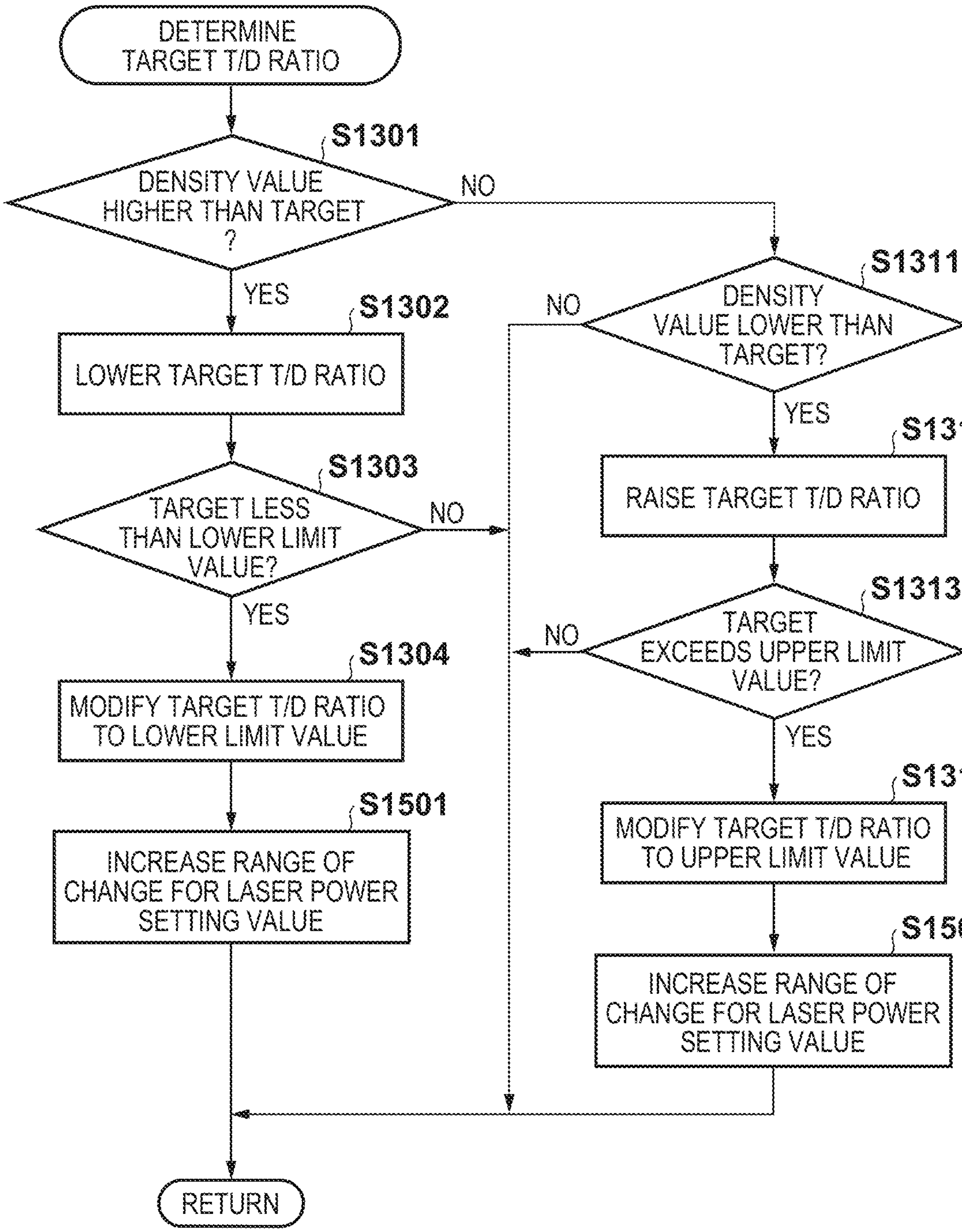

DETERMINE TARGET T/D RATIO
S1301
DENSITY VALUE HIGHER THAN TARGET ?
NO
YES
S1302
LOWER TARGET T/D RATIO
S1303
TARGET LESS THAN LOWER LIMIT VALUE?
NO
YES
S1304
MODIFY TARGET T/D RATIO TO LOWER LIMIT VALUE
S1305
MODIFY FEEDBACK RATE
S1311
DENSITY VALUE LOWER THAN TARGET?
NO
YES
S1312
RAISE TARGET T/D RATIO
S1313
TARGET EXCEEDS UPPER LIMIT VALUE?
NO
YES
S1314
MODIFY TARGET T/D RATIO TO UPPER LIMIT VALUE
S1315
MODIFY FEEDBACK RATE
RETURN

FIG. 14


START
FORM CHART
S1101
DETECT CHART
S1102
CORRECT LOOKUP TABLE
(CHANGE LASER POWER SETTING VALUE
FOR SOLID-COLOR DENSITY)
S1401
END

F I G. 15


DETERMINE TARGET T/D RATIO
S1301
DENSITY VALUE HIGHER THAN TARGET ?
NO
YES
S1302
LOWER TARGET T/D RATIO
S1303
TARGET LESS THAN LOWER LIMIT VALUE?
NO
YES
S1304
MODIFY TARGET T/D RATIO TO LOWER LIMIT VALUE
S1501
INCREASE RANGE OF CHANGE FOR LASER POWER SETTING VALUE
S1311
DENSITY VALUE LOWER THAN TARGET?
NO
YES
S1312
RAISE TARGET T/D RATIO
S1313
TARGET EXCEEDS UPPER LIMIT VALUE?
NO
YES
S1314
MODIFY TARGET T/D RATIO TO UPPER LIMIT VALUE
S1502
INCREASE RANGE OF CHANGE FOR LASER POWER SETTING VALUE
RETURN

TONE CORRECTION PROCESS THAT CORRECTS TONE OF IMAGE FORMED BY IMAGE FORMING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to tone correction processes that correct the tone of images formed by an image forming apparatus.

2. Description of the Related Art

Electrophotographic image forming apparatuses include developing units that hold two-component developer containing a nonmagnetic toner and a magnetic carrier. Such an image forming apparatus forms images using the toner held in the developing unit. By controlling a ratio of toner mass to the total mass of the developing material held in the developing unit (called a "T/D ratio" hereinafter) to achieve a target ratio, the image forming apparatus controls the density of the images it forms to achieve a target density. This control is referred to as Automatic Toner Replenishment (ATR) control.

Japanese Patent Laid-Open No. 2004-271834 discloses an image forming apparatus that controls an amount of toner with which a developing unit is replenished based on a result of measuring a measurement image in order to control the T/D ratio of developing material held in the developing unit to achieve a target ratio.

The image forming apparatus expresses the tone of images using an area coverage modulation method. For example, the image forming apparatus detects a measurement image formed using predetermined process conditions and then executes tone correction control that generates conversion conditions for converting image data based on a result of the detection.

Although the T/D ratio is adjusted through the ATR control, toner scatter will occur with ease if the T/D ratio exceeds an upper limit value. This can result in the interior of the image forming apparatus being soiled by toner, images becoming fogged and soiled, and so on. On the other hand, carrier adhesion will occur if the T/D ratio drops below a lower limit value. Carrier adhesion is a phenomenon in which the carrier is developed along with the toner. If carrier adhesion occurs, image problems in which the image appears patchy can occur as a result. Accordingly, the T/D ratio is adjusted so as not to exceed or drop below the upper limit value and the lower limit value, respectively. The upper limit value and the lower limit value will be referred to as "T/D ratio limiters".

However, in the case where the T/D ratio is restricted to the upper limit value, it may become impossible to suppress the toner from taking on excessively high charge. On the other hand, in the case where the T/D ratio is restricted to the lower limit value, it may become impossible to increase the toner charge amount to a target amount. In this manner, ATR control cannot correct the T/D ratio beyond the T/D ratio limiters, making it impossible to control the toner charge amount to the target amount; as a result a difference between a density of an output image and a target density may increase.

SUMMARY OF THE INVENTION

The present invention reduces a difference between a density of an output image and a target density.

The present invention provides an image forming apparatus comprising the following elements. A conversion unit is configured to convert image data using a conversion condition. An image forming unit is configured to form an image on

an image carrier based on the image data converted by the conversion unit. The image forming unit includes a developing portion configured to, using toner, develop an electrostatic latent image formed based on the image data converted by the conversion unit. A detection unit is configured to detect a toner density in the developing portion. A replenishment control unit is configured to, based on a result of the detection performed by the detection unit, control an amount of toner the developing portion is replenished with so that the toner density in the developing portion reaches a target density. A measurement unit is configured to measure a measurement image formed on the image carrier by the image forming unit. A first determination unit is configured to cause the image forming unit to form a first measurement image, cause the measurement unit to measure the first measurement image, and determine the target density based on a result of measuring the first measurement image. A correction unit is configured to cause the image forming unit to form a second measurement image, cause the measurement unit to measure the second measurement image, and correct the conversion condition based on a result of measuring the second measurement image and a correction condition. A second determination unit is configured to determine the correction condition based on the target density determined by the first determination unit.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an overall cross-sectional view of an image forming apparatus.

FIG. **2** is a block diagram illustrating functions related to image processing.

FIG. **3** is a block diagram illustrating functions related to control of image forming conditions.

FIG. **4** is a diagram illustrating an example of a laser power setting value.

FIG. **5** is a diagram illustrating an example of a reference chart.

FIG. **6** is a diagram illustrating a relationship between the laser power setting value and a density value.

FIG. **7** is a diagram illustrating an example of a tone correction chart.

FIG. **8** is a diagram illustrating an example of a tone chart.

FIG. **9** is a diagram illustrating a relationship between the signal value of a density signal and a density value.

FIG. **10** is a diagram illustrating an example of an ATR chart.

FIG. **11**A is a flowchart illustrating multitone control.

FIG. **11**B is a flowchart illustrating a process for determining a target T/D ratio.

FIG. **12** is a flowchart illustrating toner replenishment amount control.

FIG. **13** is a flowchart illustrating a process for determining a target T/D ratio.

FIG. **14** is a flowchart illustrating multitone control.

FIG. **15** is a flowchart illustrating a process for determining a target T/D ratio.

DESCRIPTION OF THE EMBODIMENTS

Overall Configuration of Image Forming Apparatus

FIG. **1** is a diagram illustrating an overall cross-sectional view of an image forming apparatus **100**. The image forming apparatus **100** is a copy machine capable of forming multicolor images on sheets (recording paper, OHP sheets, cloth, resin, and the like) using an electrophotographic technique, and includes a printer unit **10** and a reader unit **20**.

The printer unit **10** is an example of an image forming unit that forms an image on an image carrier based on image data converted by a conversion unit. The printer unit **10** includes, as image forming units that form toner images, first, second, third, and fourth image forming sections (stations) for forming yellow, magenta, cyan, and black images, respectively. Aside from the toner that is used, each image forming section has the same configuration. A printer control unit **40** controls a laser driver **41**, a high voltage driver **42**, and the four image forming sections, based on image signals output from the reader unit **20**.

Each image forming section is provided with a photosensitive drum **1**, which is a cylindrical photosensitive member that serves as an image carrier. The photosensitive drum **1** rotates in the direction of an arrow R1. The surface of the photosensitive drum **1** is charged to a uniform potential by a charging roller **2** that serves as a charging unit. The high voltage driver **42** supplies a predetermined charging voltage to the charging roller **2**. A laser beam scanner **3** that serves as an exposure unit forms an electrostatic latent image by irradiating the surface of the photosensitive drum **1** with a beam of light while a light amount is controlled by the laser driver **41**. A developing unit **4** is a developing portion that develops the electrostatic latent image using toner; a predetermined developing voltage is supplied thereto from the high voltage driver **42**, causing the toner to adhere to the electrostatic latent image and developing the electrostatic latent image into a toner image (a visual image). The developing unit **4** according to the present embodiment holds a two-component developer containing nonmagnetic resin toner particles (toner) as a developing material and magnetic carrier particles (carrier). The developing unit **4** includes a developing sleeve **44** that is disposed opposing the photosensitive drum **1** and that serves as a developing material bearing member. The electrostatic latent image on the photosensitive drum **1** is developed into a toner image by supplying toner to the photosensitive drum **1** from the developing material borne on the developing sleeve **44**. A primary transfer roller **6** executes a primary transfer of the toner image onto an intermediate transfer belt **51**. The intermediate transfer belt **51** functions as an image carrier and as an intermediate transfer member. Toner that remains following the primary transfer is removed from the surface of the photosensitive drum **1** by a cleaning section **7** that serves as a cleaning unit. The toner image formed on the intermediate transfer belt **51** undergoes a secondary transfer onto a sheet at a secondary transfer roller pair (an inner roller **71** and an outer roller **72**). The toner image that has undergone the secondary transfer onto the sheet is fixed onto the sheet by a fixing section **80**.

The reader unit **20** is what is known as an image scanner. A light source **23** irradiates a document **21** placed on a document glass **22** with irradiation light. Light reflected by the document **21** forms an image on a CCD sensor **25** via an optical system **24** such as a lens or the like. The CCD sensor **25** is an image sensor that outputs an image signal in accordance with the light reflected by the document **21**. In particular, an intensity of the light reflected by the toner image indicates a reflection density (brightness value) of the toner image. A reading section configured of the light source **23**, the optical system **24**, and the CCD sensor **25** scans the entire document **21** by moving in the direction indicated by an arrow A in FIG. **1** (that is, in a sub scanning direction). An input image processing unit **26** generates image data by converting an analog image signal from the CCD sensor **25** into a digital image signal. The image data is a collection of reflection densities (brightness values). The input image processing unit **26** converts image data configured of RGB brightness values into image data configured of YMCK density values and outputs the image data to the printer control unit **40**.

FIG. **2** is a block diagram illustrating functions related to image processing. The input image processing unit **26** includes a brightness/density conversion unit **201** that converts the reflection densities (brightness values) in a pattern image formed on a sheet into density values. The printer control unit **40** includes a CPU **210**, a ROM **220**, and a RAM **230**. The CPU **210** realizes various types of functions related to image processing by executing programs stored in the ROM. Note that an ASIC (Application-Specific Integrated Circuit), a DSP (a Digital Signal Processor), or the like may be used along with the CPU **210** or instead of the CPU **210**.

The CPU **210** functions as a unit that sets a laser power (exposure amount), which is one example of image forming parameters, in the laser driver **41**. For example, based on pattern data or other control data, the CPU **210** sets n laser powers, from a first step to an nth step, sequentially in the laser driver **41**. The laser driver **41** controls the laser beam scanner **3** to output the beam of light based on the specified laser power. As a result, an electrostatic latent image serving as the basis of toner images having respectively different image densities is formed on the photosensitive drum **1**.

An output image processing unit **211** executes image processing (gamma correction and the like) on density data that has been input from the brightness/density conversion unit **201** as an image signal. For example, the output image processing unit **211** determines a mixing amount for the respective color components of yellow, magenta, cyan, and black so as to output images correctly with the intended coloration. A gamma correction unit **212** corrects gamma properties of an output image using a gamma lookup table (GLUT) for maintaining desired tone characteristics. The GLUT is an example of conversion conditions for converting the image data. The gamma correction unit **212** is an example of a conversion unit that converts image data using conversion conditions. A dithering unit **213** carries out a dithering process for half-tones. For example, the dithering unit **213** selects a dithering pattern corresponding to an input density value and executes the dithering process using the selected dithering pattern. In this manner, the dithering unit **213** functions as a dithering unit that selects a dithering pattern based on a density signal converted using a lookup table and executes a dithering process.

The CPU **210** sets a predetermined charging potential for the photosensitive drum **1** in the high voltage driver **42**. The high voltage driver **42** applies a charging voltage to the charging roller **2** so that the specified charging potential is achieved. The CPU **210** sets a predetermined developing potential in the high voltage driver **42**. The high voltage driver **42** applies the developing voltage to the developing sleeve **44** of the developing unit **4** so that the specified developing potential is achieved.

Maximum Density Control

FIG. **3** is a block diagram illustrating functions related to control of image forming conditions. A solid-color density control unit **301** is a unit that controls a maximum density to a desired density by forming a reference chart on a sheet and reading the reference chart using the reader unit **20**.

By controlling the high voltage driver **42**, the solid-color density control unit **301** charges the surface of the photosensitive drum **1** so that the surface potential thereof reaches a predetermined dark area potential and also applies a predetermined developing voltage to the developing sleeve **44** of the developing unit **4**. The dark area potential of the drum is −700 V and a DC component of the developing potential is −600 V, for example. In this state, the solid-color density control unit **301** forms a plurality of solid pattern images within an A3-size range by varying the laser power (exposure amount) across a plurality of steps. FIG. **4** illustrates an example of setting values output to the laser driver **41** by the solid-color density control unit **301** when the laser power is varied across seven steps. In this example, the laser power setting values are expressed in 9 bits. That is, the maximum laser power setting value is 511, and the remaining seven setting values are therefore 160, 192, 224, 256, 288, 320, and 352. FIG. **5** illustrates a reference chart **500** formed using these setting values. As shown in FIG. **5**, the reference chart **500** has seven solid pattern images whose densities differ according to the laser power (exposure amount).

The reader unit **20** reads the reference chart **500** placed on the document glass **22** and detects the brightness value of each solid pattern image. The input image processing unit **26** then converts the brightness values into density values and sends the density values to the output image processing unit **211** of the printer control unit **40**.

Each of the density values in the seven solid pattern images is stored in association with the laser power setting value used when the printer unit **10** forms that solid pattern image. FIG. **6** illustrates data indicating a relationship between the density values in the solid pattern images and the laser power setting values. The solid-color density control unit **301** compares the density value (measured value) in each solid pattern image with a target density value and searches out measured values that exceed the target density value. For example, the solid-color density control unit **301** compares the measured value corresponding to a setting value with the target density value, in order from the lowest setting value to the highest setting value. The solid-color density control unit **301** then takes the laser power setting value corresponding to the measured value that exceeds the target density value as LPhigh, and takes the laser power setting value one step lower than LPhigh as LPlow. At this time, the solid-color density control unit **301** calculates a laser power setting value LPset corresponding to the target density value by performing linear interpolation using two points, namely a measured density value corresponding to the setting value LPlow and a measured density value corresponding to the setting value LPhigh. As shown in FIG. **6**, the target density value is set to 1.7, for example. Note, however, that the target density value is not limited to this value.

Meanwhile, in the case where all of the measured density values are lower than the target density value, the solid-color density control unit **301** takes the laser power setting value whose measured density value is highest as LPhigh and takes the laser power setting value one step lower than the laser power setting value LPhigh as LPlow. The solid-color density control unit **301** then extrapolates (linearly interpolates) the measured density value corresponding to the laser power setting value LPhigh and the measured density value corresponding to the laser power setting value LPlow, and then calculates the laser power setting value LPset corresponding to the target density value. In the case where all of the measured density values are higher than the target density value, the solid-color density control unit **301** takes the laser power setting value whose measured density value is lowest as LPlow and the laser power setting value one step higher than the laser power setting value LPlow as LPhigh. The solid-color density control unit **301** then extrapolates (linearly interpolates) the measured density value corresponding to the laser power setting value LPhigh and the measured density value corresponding to the laser power setting value LPlow, and then calculates the laser power setting value LPset corresponding to the target density value.

Tone Correction (Pascal LUT Correction)

Once the laser power setting value LPset has been determined, a Pascal LUT correction unit **302** executes tone correction. Once the tone correction has been executed, a gamma lookup table (GLUT) is generated. In other words, the tones of the image formed by the printer unit **10** are corrected to take on target tones. As shown in FIG. **3**, a GLUT **303** used by the gamma correction unit **212** is a γLUT obtained by multiplying two lookup tables. A Pascal LUT **304** is a lookup table corrected by the Pascal LUT correction unit **302**, and is updated after the maximum density is corrected. A PreGLUT **305** is a lookup table corrected by a multitone control unit **306** during image forming operations, and is corrected frequently through comparison with the Pascal LUT **304**. The Pascal LUT **304** corrects long-term tone fluctuations, whereas the PreGLUT **305** corrects short-term tone fluctuations. Note that the multitone control unit **306** is an example of a correction unit that causes the image forming unit to form a second measurement image (example: the pattern image), causes a measurement unit to measure the second measurement image, and corrects the conversion conditions based on a result of measuring the second measurement image and correction conditions (example: a feedback rate).

FIG. **7** is a diagram illustrating an example of a tone correction chart **700** formed on a sheet S when carrying out tone correction. The Pascal LUT correction unit **302** sets a predetermined drum potential in the high voltage driver **42** and sets the laser power setting value LPset in the laser driver **41**. The printer unit **10** forms the tone correction chart **700** using process conditions that have been set. The tone correction chart **700** includes ten pattern images, generated using black toner, that have mutually different densities. Each pattern image is an image that has undergone dithering by the dithering unit **213** using a dithering pattern based on the density value. "Dithering pattern" refers to a method for disposing halftone dots, or in other words, how sparse the halftone dots are and the size of the halftone dots. Hereinafter, it is assumed that the Pascal LUT correction unit **302** generates the tone correction chart **700** by controlling the output image processing unit **211**, the gamma correction unit **212**, and the dithering unit **213**.

Furthermore, it is assumed that the output image processing unit **211** handles density information input from the input image processing unit **26** in an 8-bit resolution. The maximum density is thus expressed as FF in hexadecimals. Here, ten steps' worth of dithering patterns corresponding to FF, E0, C0, A0, 90, 80, 60, 40, 20, and 10, which are the signal values indicating ten steps' worth of density information, are prepared. In other words, the ten steps' worth of dithering patterns are specified by the respective signal values of FF, E0, C0, A0, 90, 80, 60, 40, 20, and 10. The output image processing unit **211** outputs, to the gamma correction unit **212**, the signal values corresponding to the ten steps' worth of density information that has been input. The gamma correction unit **212** converts the input density signals by referring to the GLUT **303**, and outputs the converted signals to the dithering unit **213**. Note that when the tone correction is performed using the reader unit **20**, the GLUT **303** may output a signal value (input signal) corresponding the density information as a density signal (output signal) to the dithering unit **213** without correcting the signal value. The dithering unit **213** selects a dithering pattern corresponding to the converted density signals and executes the dithering process. The printer unit forms the tone correction chart **700** on the sheet S based on the image data (measurement image data) that has undergone the dithering.

In the case where the user has placed the tone correction chart **700** on the document glass **22** of the reader unit **20** and instructed the tone correction chart **700** to be read using an operating unit (not shown), the reader unit **20** measures the brightness values of the tone correction chart **700**. The input image processing unit **26** then converts the brightness values of the tone correction chart **700** into density values using the brightness/density conversion unit **201**, and outputs the density values to the printer control unit **40**. The Pascal LUT correction unit **302** generates the Pascal LUT **304** so that the density value of each pattern image matches the target density value and stores the Pascal LUT **304** in the RAM **230**.

After the tone correction is performed using the reader unit **20**, the GLUT **303** us updated based on the GLUT **303**, the Pascal LUT **304** and the PreGLUT **305**. In this case, the Pascal LUT correction unit **302** set one with a correction coefficient of the PreGLUT **305** such that the PreGLUT **305** converts the input signal into the output signal without correcting the input signal. Note that when the gamma correction unit **212** does not convert the density signal based on the GLUT **303** in order to perform the tone correction, the GLUT **303** is created based on the Pascal LUT **304** and the PreGLUT **305**.

Note that the density of images formed by the printer unit **10** also varies depending on environmental conditions (temperature, humidity), the number of pages to be printed, and so on, and it is therefore necessary to periodically correct the GLUT **303**. However, it is necessary to print the tone correction chart **700** in order to correct the Pascal LUT **304**, which consumes sheets, places a burden on a user by requiring the user to place the tone correction chart **700** on the document glass **22**, and so on. Accordingly, the image forming apparatus **100** corrects the PreGLUT **305** without using the tone correction chart **700**, and updates the GLUT **303** based on the Pascal LUT **304** and the PreGLUT **305**. Through this, the image forming apparatus **100** can reduce the burden involved with the user placing the tone correction chart **700** on the document glass **22** while also keeping the image density at an appropriate density.

PreGLUT Correction

Density correction (multitone control), through which the multitone control unit **306** corrects the PreGLUT **305** during image forming operations, will be described based on FIG. **11**A. The density correction is control in which the multitone control unit **306** causes the printer unit **10** to form a plurality of pattern images having different tones on the intermediate transfer belt **51**, causes a pattern sensor **317** to detect the densities of the pattern images, and corrects the PreGLUT **305** based on the results of detecting the pattern images. Note that the pattern sensor **317** is an example of a measurement unit that measures a measurement image formed on an image carrier by an image forming unit. The CPU **210** updates the GLUT **303** based on the PreGLUT **305**. In this manner, the multitone control unit **306** functions as a control unit that controls image forming conditions (example: allocation of dithering patterns) by feeding back the density value of a second toner image formed upon the intermediate transfer belt **51**.

In S**1101**, the multitone control unit **306** controls the printer unit **10** to form a plurality of pattern images having different tones (a tone chart **800**) on the intermediate transfer belt **51**. For example, the multitone control unit **306** controls the gamma correction unit **212** and corrects a predetermined five steps' worth of signal values (512, 320, 256, 192, and 128) based on the GLUT **303** held in the RAM **230** immediately before the image formation. Then, the multitone control unit **306** controls the dithering unit **213** to select a dithering pattern corresponding to the signal values corrected by the gamma correction unit **212** and execute the dithering process. As shown in FIG. **8**, the tone chart **800**, which includes five pattern images, is formed on the intermediate transfer belt **51**.

In S**1102**, the multitone control unit **306** measures the density of each pattern image in the tone chart **800** using the pattern sensor **317**, which is disposed in the vicinity of the intermediate transfer belt **51**. The pattern sensor **317** outputs signals indicating results of reading each pattern included in the tone chart **800**. The pattern sensor **317** is, for example, an optical sensor having a light-emitting portion and a light-receiving portion. Using a conversion table stored in advance, the multitone control unit **306** converts each output signal from the pattern sensor **317** into a density value Dm.

In S**1103**, the multitone control unit **306** corrects the PreGLUT **305**, which is a lookup table. For example, the multitone control unit **306** compares the detected density values Dm with target density values Dt obtained using the GLUT **303**. As shown in FIG. **9**, the multitone control unit **306** corrects the PreGLUT **305** in the case where a difference between the density values Dm corresponding to the respective signal values (512, 320, 256, 192, and 128) and the density values Dt corresponding to the respective signal values obtained using the GLUT **303** (512, 320, 256, 192, and 128) is greater than a predetermined value. For example, the multitone control unit **306** calculates a difference dΔ, between the density value Dm corresponding to a signal value and the target density value Dt corresponding to a signal value obtained using the GLUT **303**, and determines whether or not the difference dΔ exceeds a threshold th. If the difference dΔ exceeds the threshold th, the multitone control unit **306** corrects the PreGLUT **305** so that the difference dΔ is 0 or is no greater than the threshold th. In this manner, the multitone control unit **306** corrects the PreGLUT **305** so as to increase the density of the toner image in the case where the density value obtained by the pattern sensor **317** is lower than the target density value. For example, the multitone control unit **306** changes the dithering pattern allocated to the density signal so as to increase the density of the toner image in the case where the obtained density value is lower than the target density value. Likewise, the multitone control unit **306** corrects the PreGLUT **305** so as to reduce the density of the toner image in the case where the density value obtained by the pattern sensor **317** is higher than the target density value. For example, the multitone control unit **306** changes the dithering pattern allocated to the density signal so as to reduce the density of the toner image in the case where the obtained density value is higher than the target density value.

Note that the multitone control unit **306** may determine whether or not the density value Dm of the maximum density image which is generated using FF as the signal value of the density signal exceeds the desired target density value Dt. Then, in the case where the density value Dm exceeds the desired target density value Dt, the multitone control unit **306** may correct the PreGLUT **305** so that the dithering pattern for maximum density value is replaced with a dithering pattern for a lower density value. This is called LUT trimming. On the other hand, in the case with the density value Dm corresponding to the signal value FF does not meet the desired target density value Dt, the PreGLUT **305** may be corrected so that the dithering pattern for maximum density value (the signal value FF) is replaced with a dithering pattern that can form a higher-density image. The multitone control unit **306** also rearranges the dithering pattern for halftone regions (halftone areas) formed by signal values that are between FF and 0. The multitone control unit **306** calculates a shift amount, which is an amount by which the density values Dm of four levels of halftone areas whose signal values are 320, 256, 192, and 128 are shifted from the target density value Dt. Furthermore, the multitone control unit **306** corrects the PreGLUT **305** so that the shift amount is 0.

Having corrected the PreGLUT **305**, the multitone control unit **306** updates the GLUT **303** based on the corrected PreGLUT **305** and the Pascal LUT **304**. Note that the multitone control unit **306** counts the number of images that are formed, and executes the multitone control when the counted value reaches a predetermined number (example: 82). The tone chart **800** may be formed in a blank region (between sheets) of the intermediate transfer belt **51**, in the area between the following edge of an image corresponding to a given sheet S and the leading edge of an image corresponding to the sheet S that follows thereafter. In other words, the tone chart **800** may be formed on the intermediate transfer belt **51** in a region where no image is formed, between the image for an nth page and the image for an n+1th page. Furthermore, the tone chart **800** may be generated during reverse rotation of the intermediate transfer belt **51**, executed after the formation of an image on the sheet S is complete. The counted value of the number of images formed is set to **0** when the developing unit **4**, a cartridge mounted in the image forming apparatus **100**, or the like is replaced. The cartridge is a unit in which a charging roller, a cleaning blade, and a photosensitive drum are integrated as a single entity.

ATR Control

Determining Target Density Value Dt

Next, ATR control executed by the CPU **210** of the printer control unit **40** will be described. The process for setting the target density value Dt is executed using a new developing unit and cartridge when the image forming apparatus **100** is installed. A T/D ratio determination unit **307** causes an ATR chart **1000**, shown in FIG. **10**, to be formed on the intermediate transfer belt **51** by controlling the printer unit **10**. The T/D ratio determination unit **307** detects the density of the ATR chart **1000** using the pattern sensor **317**. The T/D ratio determination unit **307** then stores the detected density as the target density value Dt of the ATR chart **1000**, in the ROM **220**.

In the present embodiment, the ATR chart **1000** is a line pattern, having a resolution of 2400 dpi, in which two-dot horizontal parallel lines and one-dot spaces are alternated repeatedly. The dithering unit **213** may employ horizontal parallel lines that correspond to the maximum density value (FF) as the dithering pattern. This is because such a dithering pattern is highly sensitive to phenomena that cause a degradation in developability, such as scraping during rotation of the developing sleeve **44**. Note that 256, which is a median value in the 512 levels, is employed as the laser power setting value.

Determining Target T/D Ratio

A method for determining the target T/D ratio will be described using FIG. **11**B. As described above, the T/D ratio is a ratio of toner mass to the total mass of the developing material held in the developing unit. The target T/D ratio is a target value for the ratio of toner to carrier in the developing unit **4**, and is updated every predetermined interval of time or the like. In S**1111**, the T/D ratio determination unit **307** forms the ATR chart **1000** on the intermediate transfer belt **51** by controlling the printer unit **10**. In S**1112**, the T/D ratio determination unit **307** detects the density of each pattern image (see FIG. **10**) in the ATR chart **1000** using the pattern sensor **317**. In S**1113**, the T/D ratio determination unit **307** determines the target T/D ratio based on a density value obtained from the ATR chart **1000**. For example, the T/D ratio determination unit **307** compares the detected density value (measured value) with the target density value Dtgt held in the ROM **220**. If the density value Datr of the ATR chart **1000** is lower than the target density value Dtgt, it is thought that the developability has dropped due to a drop in the toner charge amount. Accordingly, the T/D ratio determination unit **307** corrects the target T/D ratio so as to reduce the T/D ratio in the developing unit **4** and increase the toner charge amount. On the other hand, if the density value Datr of the ATR chart **1000** is higher than the target density value Dtgt, it is thought that the toner charge amount has risen. Accordingly, the T/D ratio determination unit **307** corrects the target T/D ratio so as to increase the T/D ratio in the developing unit **4** and reduce the toner charge amount. The corrected T/D ratio is stored in the RAM **230**. The target T/D ratio is used by a replenishment control unit **308** in order to adjust a toner replenishment amount. In this manner, the T/D ratio determination unit **307** functions as a target value determination unit that determines a target value for the T/D ratio in accordance with the density value of a first toner image (the ATR chart **1000**) formed on the intermediate transfer belt **51**. In other words, the T/D ratio determination unit **307** is an example of a first determination unit that causes the image forming unit to form a first measurement image, causes the measurement unit to measure the first measurement image, and determines the target density based on the result of measuring the first measurement image.

Toner Replenishment Amount Control

Toner replenishment amount control will be described using FIG. **12**. Note that the replenishment control unit **308** functions as a replenishment amount control unit that controls the amount of toner with which a toner agitating unit **331** in the developing unit **4** is replenished from a toner receptacle **330** based on the ratio of toner to carrier (the T/D ratio) in the developing unit **4**.

In S**1201**, the replenishment control unit **308** measures the T/D ratio of the developing material using a density sensor **311**. The density sensor **311** is an example of a detection unit that detects a toner density in the developing portion. For example, the replenishment control unit **308** detects a magnetic permeability of the developing material using the density sensor **311**, which is an inductance sensor or the like, and converts the magnetic permeability into the T/D ratio of the developing material within the developing unit **4**. In this manner, the density sensor **311** functions as a detection unit that detects the ratio of toner to the developing material held in the developing unit **4** (the toner density). The density sensor **311** may be a magnetic permeability detection unit that detects the magnetic permeability of the developing material in the developing portion. Meanwhile, the replenishment control unit **308** is an example of a replenishment control unit that, based on a result of the detection performed by the detection unit, controls the amount of toner the developing portion is replenished with so that the toner density in the developing portion reaches a target density.

In S**1202**, the replenishment control unit **308** compares the T/D ratio detected by the density sensor **311** with the target T/D ratio determined by the T/D ratio determination unit **307**, and determines whether or not the T/D ratio is lower than the target T/D ratio. The process advances to S**1205** if the T/D ratio of the developing material is lower than the target T/D ratio. In S**1205**, the replenishment control unit **308** increases the toner replenishment amount in a toner replenishing unit **310**.

The process advances to S**1203** if it is determined in S**1202** that the T/D ratio of the developing material is not lower than the target T/D ratio. In S1203, the replenishment control unit **308** determines whether or not the T/D ratio of the developing material is higher than the target T/D ratio. If the T/D ratio of the developing material is higher than the target T/D ratio, it can be said that there is too much toner relative to the carrier, and thus the process advances to S1204. However, the process ends if the T/D ratio of the developing material is not higher than the target T/D ratio.

In S1204, the replenishment control unit **308** reduces the toner replenishment amount in the toner replenishing unit **310**. The toner replenishing unit **310** is a mechanism that replenishes the toner agitating unit **331** of the developing unit **4** with toner from the toner receptacle **330**. Through this, the T/D ratio of the developing unit **4** can be corrected to the target T/D ratio, and images can be formed using toner whose charge amount has been adjusted to a desired charge amount. Although the magnetic permeability is converted into the T/D ratio here, the magnetic permeability may be used as-is instead. In such a case, the target T/D ratio is converted into a target magnetic permeability and used. The toner agitating unit **331** functions as an agitating unit that agitates the toner and carrier held in the developing unit **4**.

T/D Ratio Limiters

In the present embodiment, the T/D ratio determination unit **307** corrects the target T/D ratio so as not to exceed predetermined T/D ratio limiters. In other words, the target T/D ratio is corrected so as not to exceed a given upper limit value and not to drop below a given lower limit value.

In the present embodiment, the upper limit value is set to 9%. The image can be soiled due to toner scatter, fogging, or the like if the target T/D ratio exceeds the upper limit value. On the other hand, the lower limit value is set to 6%. Image problems such as ghosting, carrier adhesion, or the like can occur if the target T/D ratio drops below the lower limit value.

Toner scatter, fogging, ghosting, and so on can be reduced by restricting the target T/D ratio using the T/D ratio limiters in this manner. However, restricting the target T/D ratio can also result in unwanted effects. Namely, there are cases where the toner charge amount cannot be correctly maintained.

Accordingly, in the present embodiment, a feedback rate determination unit **309** changes a feedback rate of the PreGLUT **305** in the case where the target T/D ratio cannot be sufficiently corrected using the T/D ratio limiters. Note that the feedback rate determination unit **309** is an example of a second determination unit that determines correction conditions based on the target density determined by the first determination unit. The PreGLUT **305** corresponds to conversion conditions for converting the image data so that the difference dΔ between the density value Dm for a signal value and the density value Dt obtained using the GLUT **303** is no greater than a threshold. The difference dΔ serves as a feedback amount. The feedback rate is a correction amount, among feedback amounts, that indicates to what degree, relative to the target density value, the density of the image formed after the PreGLUT **305** has been updated is to be corrected. For example, the feedback rate is 5% in the case where the target T/D ratio is within a range from the upper limit value to the lower limit value (a first correction condition). On the other hand, the feedback rate is 10% in the case where the target T/D ratio is outside of the range from the upper limit value to the lower limit value (a second correction condition). In this manner, a correction amount by which the conversion conditions corrected based on the second correction condition corrects a predetermined input value is greater than a correction amount by which the conversion conditions corrected based on the first correction condition corrects the predetermined input value. The feedback rate determination unit **309** determines the feedback rate so that this size relationship holds true. The feedback rate determination unit **309** functions as a feedback rate setting unit that sets the feedback rate to a first value in the case where the target T/D ratio is within a predetermined range and sets the feedback rate to a second value that is greater than the first value in the case where the target T/D ratio is outside of the predetermined range. Meanwhile, in the case where the target T/D ratio is outside of the predetermined range, the feedback rate determination unit **309** may set the feedback rate to the second value, which is greater than the first value, for a lookup table that manages the allocation of dithering patterns.

The multitone control is carried out automatically when a predetermined number of images have been formed. For example, the multitone control is executed each time 82 pages of images have been formed. As such, the multitone control is control that is executed with comparatively high frequency. Accordingly, for example, in the case where a plurality of images are formed consecutively, raising the feedback rate excessively will cause a difference between the density of images form before the multitone control is executed and the density of images formed after the multitone control is executed to increase. In other words, in the case where the PreGLUT **305** is changed excessively due to the frequently-executed multitone control, the color of the image will be corrected excessively.

However, in the case where the target T/D ratio is fixed to the T/D ratio limiters and the T/D ratio of the developing unit **4** cannot be sufficiently corrected, the toner charge amount may become unstable, which may lead to an increase in engine density fluctuations. In such a case, the feedback rate determination unit **309** sets the feedback rate to a relatively higher value than the feedback rate employed in the case where the target T/D ratio is within the range from the upper limit value to the lower limit value. As a result, the PreGLUT **305** can be corrected to a greater degree when executing the multitone control, making it possible to appropriately correct shift in the color of an image even in the case where the toner charge amount cannot be controlled to a desired charge amount.

It is especially easy for the maximum density to become unstable in a situation where the target T/D ratio is fixed to the T/D ratio limiters and cannot be controlled in a variable manner. However, by determining the feedback rate as described above, the maximum density can be stabilized as well. In other words, the feedback rate determination unit **309** sets the feedback rate for the case where the target T/D ratio cannot be controlled in a variable manner to a greater value than the feedback rate for the case where the target T/D ratio can be controlled in a variable manner. Through this, the PreGLUT **305** is corrected appropriately, and thus correction for density shifts across the entire density range, as opposed to just the maximum density, can be executed with certainty. As a result, images can be formed in a stable manner over a long period of time regardless of the usage conditions of the image forming apparatus **100**, such as the ratio of printed surface area in the page that is printed.

A method for determining the target T/D ratio that includes a process for modifying the feedback rate will be described using FIG. **13**. This flowchart illustrates S1113, shown in FIG. 11B, in detail.

In S1301, the T/D ratio determination unit **307** compares the density value measured from the ATR chart **1000** to the target density value, and determines whether or not the measured density value is higher than the target density value. The process advances to S1302 in the case where the measured density value is higher than the target density value.

In S1302, the T/D ratio determination unit **307** lowers the target T/D ratio set in the replenishment control unit **308** by one level. The T/D ratio determination unit **307** lowers the target T/D ratio by 1%, for example. In this manner, the T/D ratio determination unit **307** functions as a unit that lowers the target value in the case where the density value obtained by the pattern sensor **317** is higher than the target density value. In S**1303**, the T/D ratio determination unit **307** determines whether or not the target T/D ratio is lower than the lower limit value. The process advances to S**1304** in the case where the target T/D ratio is lower than the lower limit value. In S**1304**, the T/D ratio determination unit **307** modifies the target T/D ratio to the lower limit value (that is, substitutes the lower limit value for the target T/D ratio). In this manner, the T/D ratio determination unit **307** functions as a unit that modifies the target T/D ratio to the lower limit value in the case where the target T/D ratio set in accordance with the density value of the ATR chart **1000** is lower than the lower limit value of the predetermined range. In S**1305**, the feedback rate determination unit **309** modifies the feedback rate. In S**1305**, the feedback rate determination unit **309** increases the feedback rate in a relative manner, as described above (example: 5%→10%).

Meanwhile, the process advances to S**1311** in the case where the density value measured in S**1301** is not higher than the target density value. In S**1311**, the T/D ratio determination unit **307** compares the density value measured from the ATR chart **1000** to the target density value, and determines whether or not the measured density value is lower than the target density value. The process advances to S**1312** in the case where the measured density value is lower than the target density value.

In S**1312**, the T/D ratio determination unit **307** raises the target T/D ratio set in the replenishment control unit **308** by one level. The T/D ratio determination unit **307** raises the target T/D ratio by 1%, for example. In this manner, the T/D ratio determination unit **307** functions as a unit that raises the target value in the case where the density value detected by the pattern sensor **317** is lower than the target density value. In S**1313**, the T/D ratio determination unit **307** determines whether or not the target T/D ratio is higher than the upper limit value. The process advances to S**1314** in the case where a target T/D ratio is higher than the upper limit value. In S**1314**, the T/D ratio determination unit **307** modifies the target T/D ratio to the upper limit value (that is, substitutes the upper limit value for the target T/D ratio). In this manner, the T/D ratio determination unit **307** functions as a unit that modifies the target T/D ratio to the upper limit value in the case where the target T/D ratio determined in accordance with the density value of the ATR chart **1000** is higher than the upper limit value of the predetermined range. In S**1315**, the feedback rate determination unit **309** modifies the feedback rate. In S**1315**, the feedback rate determination unit **309** increases the feedback rate in a relative manner, as described above (example: 5%→10%).

The image forming apparatus **100** according to the present embodiment as described thus far controls the amount of toner with which the developing unit **4** is to be replenished from the toner receptacle **330** in accordance with the T/D ratio of the developing unit **4**. The image forming apparatus **100** determines the target T/D ratio in accordance with the density value of the ATR chart **1000** formed on the intermediate transfer belt **51**. Furthermore, the image forming apparatus **100** controls the conversion conditions by feeding back the density value of the tone chart **800** formed on the intermediate transfer belt **51**. In particular, the image forming apparatus **100** sets a correction condition for correcting the conversion conditions to a first correction condition in the case where the target T/D ratio is within the predetermined range, and sets the correction condition for correcting the conversion conditions to a second correction condition, whose correction amount for a predetermined signal value is greater than that of the first correction condition, in the case where the target T/D ratio is outside of the predetermined range. Through this, the stability of maximum densities can be maintained even if the ratio between the toner and the carrier has been restricted to the predetermined range. The image forming apparatus **100** corrects the conversion conditions so that the density of the toner image increases in the case where the density value obtained by the pattern sensor **317** is lower than the target density value, and corrects the conversion conditions so that the density of the toner image decreases in the case where the density value obtained by the pattern sensor **317** is higher than the target density value. The conversion conditions are, for example, the PreGLUT **305**, which is a lookup table that manages the allocation of dithering patterns. Note that the image forming apparatus **100** changes the dithering pattern allocated to the density signal so as to increase the density of the toner image in the case where the density value obtained by the pattern sensor **317** is lower than the target density value. Likewise, the image forming apparatus **100** changes the dithering pattern allocated to the density signal so as to reduce the density of the toner image in the case where the density value obtained by the pattern sensor **317** is higher than the target density value.

The image forming apparatus **100** can suppress toner scatter, fogging, and so on by modifying the target T/D ratio to the upper limit value in the case where the target T/D ratio determined in accordance with the density value of the ATR chart **1000** exceeds the upper limit value.

Likewise, the image forming apparatus **100** can suppress ghosting, carrier adhesion, and so on by modifying the target T/D ratio to the lower limit value in the case where the target T/D ratio determined in accordance with the density value of the ATR chart **1000** is lower than the lower limit value.

The image forming apparatus **100** lowers the target T/D ratio in the case where the density value obtained by the pattern sensor **317** is higher than the target density value and raises the target T/D ratio in the case where the density value obtained by the pattern sensor **317** is lower than the target density value. Through this, the T/D ratio of the developing material in the developing unit **4** is controlled correctly.

In the present embodiment, the T/D ratio of the developing material is detected using an inductance sensor so as to detect the magnetic permeability when the developing material is in a mixed state; however, the method for detecting the T/D ratio in the present invention is not limited thereto. In other words, a sensor that detects another physical amount that correlates with the T/D ratio may be used.

Second Embodiment

In the multitone control according to the first embodiment, the allocation of dithering patterns to density signals is changed (that is, the laser exposure time is changed) as a measure when the maximum density has shifted from the target density (S**1103**). In a second embodiment, however, the laser power is controlled in a variable manner in the multitone control as a measure when the maximum density has shifted from the target density.

FIG. **14** illustrates the multitone control according to the second embodiment, where S**1103** has been replaced with S**1401**. In S**1401**, the multitone control unit **306** corrects a lookup table. However, in the case where the measured maximum density is higher than the target density by no less than a predetermined value, the maximum density control unit **301** lowers the laser power setting value by one step. In the case where the measured maximum density is lower than the target density by no less than a predetermined value, the maximum density control unit **301** raises the laser power setting value by one step. "One step" corresponds to one of the seven levels shown in FIG. **4**. Although the laser power can be controlled across seven levels in the second embodiment, the number of levels across which the laser power can be controlled may be determined as appropriate. In the case where the resolution of the laser power setting value is 9 bits, the maximum density control unit **301** may change the laser power setting value one level at a time in a range from 0 to 511. Note that halftones aside from the maximum density are corrected using the feedback rate for the PreGLUT **305** as described above.

As described in the first embodiment, the PreGLUT **305** is corrected so as to lower the density in the case where the measured maximum density is higher than the target density (that is, the dithering pattern may be changed). In other words, in the case where the density of an image formed using a predetermined laser power is higher than a desired density, the exposure time may be shortened. However, shortening the exposure time may produce jaggies in text, lines, and so on, which in turn can reduce the image quality. Accordingly, the maximum density control unit **301** can suppress the exposure time from being shortened excessively by changing the laser power setting value.

On the other hand, the PreGLUT **305** is corrected so as to raise the density in the case where the measured maximum density is lower than the target density (that is, the dithering pattern may be changed). In this manner, although the correction can be carried out by reducing the amount by which the exposure time is shortened, the maximum density cannot be corrected if the amount by which the exposure time is shortened has been lowered to a lower limit. Accordingly, control for changing the laser power setting value and control for changing the dithering pattern may be carried out in tandem.

Correction of Target T/D Ratio in ATR Control

In the second embodiment, the maximum density control unit **301** may increase the range across which the laser power setting value is changed in the case where the target T/D ratio cannot be corrected using the T/D ratio limiters in the ATR control. FIG. **15** illustrates a method for determining the target T/D ratio according to the second embodiment. For example, in the case where the measured maximum density is lower than the target density by no less than a predetermined value, the maximum density control unit **301** raises the range across which laser power setting value is changed, and raises the laser power setting value by two steps, in S**1501**. On the other hand, in the case where the measured maximum density is higher than the target density by no less than a predetermined value, the maximum density control unit **301** raises the range across which laser power setting value is changed, and lowers the laser power setting value by two steps, in S**1502**. In this manner, the maximum density control unit **301** includes an increasing unit that increases the range across which the laser power setting value is changed. The feedback rate determination unit **309** may manage the increase in the range of the change. Accordingly, the maximum density control unit **301**, the feedback rate determination unit **309**, and so on function as a unit that increases the range of change for an exposure amount, serving as an image forming condition, when the target T/D ratio is outside of the range from the upper limit value to the lower limit value.

As described above, in a situation where the target T/D ratio is set to the T/D ratio limiters and cannot be corrected any further, the toner charge amount may not stabilize and engine density fluctuations may increase. It is especially easy for the maximum density to become unstable in such a situation, where the toner charge amount is unstable. Accordingly, the image forming apparatus **100** increases the range of change for the exposure amount, which is an image forming condition, in the case where the target T/D ratio is outside of the predetermined range. In other words, the color can be stabilized by increasing the range across which the laser power setting value is changed in addition to correcting the PreGLUT **305**.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application Nos. 2013-184339, filed Sep. 5, 2013 and 2014-161898, filed Aug. 7, 2014, which are hereby incorporated by reference herein in their entirety.

What is claimed is:

1. An image forming apparatus comprising:

a conversion unit configured to convert image data using a conversion condition;

an image forming unit configured to form an image based on the image data converted by the conversion unit, the image forming unit including an image carrier, an exposure unit configured to expose the image carrier to form an electrostatic latent image, a developing unit configured to develop the electrostatic latent image by using developing material that includes toner and carrier, and an intermediate transfer member onto which the image that is formed on the image carrier is transferred;

a detection unit configured to detect a toner density of the developing material in the developing unit;

a replenishing unit configured to replenish the toner in the developing unit;

a replenishment control unit configured to, based on the toner density detected by the detection unit and a target density, control the replenishing unit;

a measurement unit configured to measure a measurement image formed on the intermediate transfer member by the image forming unit;

a first determination unit configured to control the image forming unit to form a first measurement image, control the measurement unit to measure the first measurement image, and determine the target density based on a measuring result of the first measurement image;

a correction unit configured to control the image forming unit to form a second measurement image, control the measurement unit to measure the second measurement image, and correct the conversion condition based on a measuring result of the second measurement image and a correction condition; and

a second determination unit configured to determine the correction condition based on the target density determined by the first determination unit.

2. The image forming apparatus according to claim **1**,

wherein the second determination unit is further configured to determine a first correction condition as the correction condition in the case where the target density determined by the first determination unit is within a predetermined range, and determine a second correction condition that is different from the first correction condition as the correction condition in the case where the target density determined by the first determination unit is outside of the predetermined range.

3. The image forming apparatus according to claim **2**, wherein a correction amount by which the conversion condition corrected based on the second correction condition corrects a predetermined input value is greater than a correction amount by which the conversion condition corrected based on the first correction condition corrects the predetermined input value.

4. The image forming apparatus according to claim **1**, wherein the conversion condition is a lookup table that manages the allocation of dithering patterns;

the correction condition is a feedback rate for the lookup table; and

the second determination unit is further configured to set the feedback rate to a first value in the case where the target density is within a predetermined range and set the feedback rate to a second value that is greater than the first value in the case where the target density is outside of the predetermined range.

5. The image forming apparatus according to claim **4**, wherein the lookup table that manages the allocation of the dithering patterns is configured by combining two lookup tables.

6. The image forming apparatus according to claim **1**, wherein in the case where the target density determined by the first measurement image exceeds an upper limit value of a predetermined range, the first determination unit modifies the target density to the upper limit value.

7. The image forming apparatus according to claim **6**, wherein the replenishment control unit is configured to control the replenishment unit based on the toner density detected by the detection unit and the modified target density.

8. The image forming apparatus according to claim **1**, wherein in the case where the target density determined in accordance with a measuring result of the first measurement image is lower than a lower limit value of a predetermined range, the first determination unit modifies the target density to the lower limit value.

9. The image forming apparatus according to claim **8**, wherein the replenishment control unit is configured to control the replenishment unit based on the toner density detected by the detection unit and the modified target density.

10. The image forming apparatus according to claim **1**, wherein the first determination unit is further configured to increase the target density in the case where the measuring result of the first measurement image is lower than a target result and decrease the target density in the case where the measuring result of the first measurement image is greater than the target result.

11. The image forming apparatus according to claim **1**, wherein the correction unit is further configured to correct the conversion condition so as to increase the density of the image to be formed by the image forming unit in the case where the measuring result of the second measurement image is lower than a target result and correct the conversion condition so as to reduce the density of the image to be formed by the image forming unit in the case where the measuring result of the second measurement image is higher than the target result.

12. The image forming apparatus according to claim **11**, wherein the conversion unit includes a lookup table configured to convert a density signal, and a dithering unit configured to select a dithering pattern based on the density signal converted by the lookup table and execute a dithering process; and

the correction unit is further configured to change the allocation of the dithering patterns to the density signal so as to increase the density of the image to be formed by the image forming unit in the case where the measuring result of the second measurement image is lower than the target result and change the allocation of the dithering patterns to the density signal so as to reduce the density of the image to be formed by the image forming unit in the case where the measuring result of the second measurement image is higher than the target result.

13. The image forming apparatus according to claim **1**, wherein the detection unit includes a magnetic permeability detection unit that detects a magnetic permeability of the developing material in the developing unit.

14. The image forming apparatus according to claim **1**, wherein the detection unit is further configured to detect a ratio of the toner mass to the total mass of the developing material that contains toner and carrier as the toner density.

15. The image forming apparatus according to claim **1**, wherein the replenishment control unit is configured to control an amount of the toner to be replenished into the developing unit by the replenishing unit based on the toner density detected by the detection unit and the target density.

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